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Some Physical and Chemical Characteristics of some "gardud" Soils in the State pf North Kordofan, Sudan

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ABSTRACT

Four locations south of Elobied town in the State of North Kordofan were selected to represent three "gardud" soils in May-June 1996. These locations were Aradayia, Umood, Bangadeed and Kaba. The results of the study showed that the soils are genetically young and are, therefore classified as Entisols and Inceptisols. The soil at Kaba is coarse loamy and those at Umood, Aradayia and Bangadeed are fine loamy. Kaolinite is the dominant clay type of the soil at Kaba, whereas smectites dominate the other three soils. The soil at Kaba is conceived to be formed in situ from sandstone as substantiated by grain-size. distribution, while the other three soils are of alluvial origin. The compactness of the soils at Aradayia, Umood, and Bangadeed is seen as a result of cementation of coarse soil separates by smectitic clays, whereas that of the soil at Kaba is envisaged as cementation by iron oxides. The soils at Aradayia, Umood, and Bangadeed are moderately fertile, whereas that at Kaba is infertile. The former three soils can be utilized under judicious cultural practices that increase soil permeability for rain water, lessen erosion hazard, and conserve soil moisture, in addition to rational application of nitrogen fertilizers. The "gardud" soils at Aradayia, Umood and Bangadeed have promising potential for field crops suited to the prevalent climate in the area, whereas the "gardud" soil at Kaba is best suited for natural grazing and tree crops, i.e., Acacia senegal (Hashab).

INTRODUCTION

The "gardud" soils are noncracking and of relatively slow permeability to rain water, but they stand a fair chance of development when compared to the sandy soils. Perhaps it is relevant to mention that there is no unified definition of what constitutes a "gardud" soil. Therefore, it is not surprising that there are several different names of this soil other than "gardud", viz: "naga'a" "atmur", "moglad","garasa", "himera", and "hadaba". An Australian advisory company(AACWTT PISCO) (1992) seven different soils in theState of North Kordofan each of which is locally known as "gardud"soil. In this respect, Hunting Technical Services (1963) named two groups of " gardud" soils, viz: Kazgail-association and Abuzabad association. Kazgail-association occurs south of Elobied where the present study was carried out. The Kazgail-association comprises two major types of soils e. The reddish brown soils of the upper sections of the slopes of the concave pediplain, and the grey brown soils of the lower slopes of the pediplain. The reddish brown soils have a surface horizon of sand or loamy sand of aeolian origin which has been stabilised by vegetation and/or iron oxides. These soils are very susceptible to wind and water erosion when over cultivated or overgrazed. Consequently, much of their surfaces are now missing and some of their sub surfaces are exposed at some places. The grey brown soils of the lower slopes of the pediplain have variable surface sand cover probably of aeolian origin also, and prone to water erosion.

The extent of "gardud" soils of the pediplain cover about 7500 km^2 (Doxiadis Associates, 1966) which represents about 14% of Kordofan region. The common general characteristics of the "gardud" soil is their partial truncation where the sandy topsoil had been removed by wind and hence the loamy subsurface was exposed. Pacheco and Dawoud (1978) reported that the "gardud" soils developed in situ from metamorphic dykes in the clay plain.

The objective of the present study was to identify, characterise and classify some "gardud" soils present along a toposequence south of Elobied town.

MATERIALS AND METHODS

a) Soil materials

Four major soil bodies south of Elobied town each of which is locally known as "gardud" were studied in May-June 1996. They occupy three positions in the toposequence, viz: Kaba occupies the upper part of the toposequence; Umood and Aradayia occupy the gently sloping part, and Bangadeed occupies the flat bottom of the toposequence. A soil profile was excavated in each soil and closely studied following the format of the FAO guidelines for soil profile description (1984). Soil samples were collected according to genetic horizons. The samples were air-dried, crushed to pass a 2 mm sieve and laboratory analyses were performed on the < 2 mm fractions. However, bulk density measurements were made on natural soil clods.

b) Chemical analysis

pH was determined on the supernatant liquid of soil : water ratio of 2:5 using H-sensing electrode, and a reference calomel Hg2C12 electrode; CaC03 was obtained by treating a soil sample with excess and then back titrated with a standard NaOH using phenolph- thalein indicator (Richards, 1954). Organic carbon was determined according to the procedure of Walkley and Black (1934). Nitrogen was obtained following the standard Kjeldahl method, (Richards, 1954). ECe, soluble anions and cations were measured on the extract of a saturated soil paste. K and Na were determined using EEI flame photometer; whereas Ca and Mg were obtained by using EDTA procedure. C03=, HC03- and Cl- were detennined as outlined by Richards (1954). The SOC was obtained by difference. The cation exchange capacity (CEC) was measured using sodium acetate as an index cation.

c) Physical analysis

Moisture retention at 330 k 'Pa and 1500 k Pa were obtained as outlined by Richards (1954). Bulk density was obtained using the paraffin wax method. Hydraulic conductivity was measured using the Darcy's equation as outlined by Klute and Dirksen (1986). Particle size distribution was determined using the pipette method (USDA,1996).

d) Grain size analysis

Soil samples from 0-50 cm depth were intermittently sieved with six amplitudes using a nest of sieves (Frisch analysette type 03.502 NO.7471). Fractions < 0.032 mm were determined. Calculations to obtain grain sizes were performed following Krumbein arithmetic scale of phi units, ø, (1934).

e) Heavy minerals

Soil particles between 0.045 and 0.5 mm from 0-50 cm depth were subjected to horseshoe magnet to remove magnetic particles. The remaining soil sample was separated into heavy and light fractions using bromoform ($CHBr_3$). The minerals of the heavy fractions were then identified using a polarising microscope.

f) X-ray diffraction (XRD) analysis

This analysis was carried on the clay separates from 25-50 cm depth. Clay samples were Mg-saturated, mounted on a slide and air- dried; other aliquots were Mg-saturated + ethylene glycol, mounted on a slide, air dried and heated to 5000C. The XRD peaks were obtained by subjecting these treated samples to Cu radiation using Siemens X- ray diffractometer. The different diffraction peaks were qualitatively and quantitatively interpreted (Jackson, 1979).

RESULTS AND DISCUSSION

The soil at Kaba was classified as Typic Ustorthents, coarse loamy, kaolinitic, isohyperthermic; that at Umood as Vertic Ustropepts, fine loamy, mixed, isohyperthermic; that at Aradayia as Vertic Ustropepts, fine loamy, smectitic, isohyperthermic; while that at Bangadeed as Vertic Ustropepts, fine loamy, mixed, isohyperthermic, (Soil Surveystaff, 1999).

The soil at Kaba site which occupies the uppermost part of the catena is well drained, with reddish brown sandy loam surface underlain by sandy clay loam; and the soil coarsens again below 55 cm (Table l). This variability in texture suggests that this soil is most likely developed in situ from a parent rock which is dominated by sandstone. The soil at Aradayia occupies the higher slopes of the catena, whereas the soil at Umood occupies the lower slopes. The latter two soils are comparatively moderately well drained, dark brown sandy clay loams to clay loams. Their soil surfaces are partially or completely eroded at some localities. The percentage of clay is lowest in the uppermost part of the catena (Kaba) and highest at the lowermost part of the catena (Bangadeed) (Table l). The available water capacity (AWC) of these soils ranged from about 10% to 20%. The soil at Kaba is coarse in texture, (i.e., high macroporosity) dominated by Kaolinite, and probably has the lowest water retention.

Table 1. Some physical properties of the studied "gardud" soils at North Kordofan (May-June 1996).

Location of the tested soil	Depth (cm)	Particle size distribution (%) Gravel	S	Si	C	Available water capacity	Bulk density (g cm^{-3})	Porosity (%)	Hydraulic conductivity (cm hr^{-1})
Kaba	0-15	29	74	10	16	14.1	1.73	35.2	9.2
	15-55	24	64	13	23	14.2	1.72	35.6	4.7
	55-90	17	69	19	12	12.4	1.91	28.5	4.7
Bangadeed	0-20	19	58	15	27	13.4	1.62	38.6	5.4
	20-40	15	46	23	31	12.0	1.76	33.3	2.4
	40-75	16	44	24	32	12.7	1.90	28.0	3.4
	75-140	14	42	27	31	12.8	1.92	27.3	4.3
Aradayia	0-20	22	69	8	23	16.7	1.87	30.0	6.0
	20-40	20	64	13	23	20.7	1.97	25.8	1.3
	40-90	20	61	14	25	19.1	1.89	29.3	1.9
Umood	0-30	20	57	16	27	9.8	1.86	30.3	5.9
	30-60	24	61	13	26	10.1	1.90	28.8	5.6
	60-90	24	63	12	25	11.5	1.83	31.5	4.5
	90-110	23	63	7	30	13.4	1.86	30.3	5.7

Values of air dry bulk density of these soils are invariably high (1.62 to 1.97 g cm-3) when compared to those of the soils in cenU•al clay plain of Sudan (1.4-1.7g cm-3). Such high values of bulk density are reflected in the relatively low percentage of total porosity (25.8% to 38.6%) and the hard nature of these soils (compacmess) that make them difficult to till. It is postulated that the compacmess of these soils is presumeably attributed to the clay particles acting as a binding material to other coarse soil separates. In this respect Doxiadis Associates (1966) viewed the compacmess of these soils as a result of the impact of rain drops that affect the loamy subsoil rendering them hard and solid.

The results showed that these soils were generally nonsaline. However, there was very slight salinity below 40 cm from the soil surface in Aradayia and Bangadeed (Table 2), which is probably a sulpha-te salinity followed by chloride and bicarbonate. However, carbonate has not been detected in these "gardud" soils. Being within the semi arid region these "gardud" soils are invariably low in organic carbon and nitrogen. Values of sodium adsorption ratio (SAR) slight sodicity (SAR 14.8-16.3) below 20 cm of the soil surface at Bangadeed location.

Table 2. Some chemical properties of the studied "gardud" soils at North Kordofan (May-June 1996).

Location of the tested soil	Depth (cm)	pH 2:5 soil:H20 ratio	Ec_e dSm $^{-1}$	$CaC0_3$	O.C.	N	CEC cmol (+)kg^{-1} soil
					%		
Kaba	0-15	7.8	0.32	0.2	0.21	0.014	2.3
	15-55	6.7	.41	nil	0.15	0.011	3.5
	55-90	6.8	1.50	nil	0.14	0.012	1.9
Bangadeed	0-20	8.2	0.5	0.8	0.53	0.029	24
	20-40	8.2	2.8	2.6	0.23	0.014	34
	40-75	7.7	6.7	3.2	0.21	0.012	30
	75-140	7.6	7.1	4.0	0.17	0.013	29
Aradayia	0-20	7.8	0.7	nil	0.23	0.015	21
	2040	8.3	2.6	0.4	0.19	0.014	20
	40-90	7.7	6.6	0.6	0.13	0.010	22
Umood	0-30	8.0	0.5	nil	0.36	0.020	22
	30-60	7.8	1.0	nil	0.31	0.018	22
	60-90	8.3	1.3	0.8	0.29	0.017	27
	90-110	8.1	1.4	1.8	0.20	0.014	26

Table 2. Continued.

Location of the tested soil	Available P	Soluble cations and anions (me $_t^{-1}$)						
	μg p_g^{-1} soil	Na	Ca	Mg	Cl	HCO3-	$SO_4^=$	SAR
Kaba	4.6	0.9	1.5	1.0	1.0	2.4	-	8.0
	7.4	1.3	3.0	1.5	2.0	1.7	1.1	0.9
	4.0	3.6	6.5	5.0	1.0	1.5	12.6	1.9
Bangadeed	2.6	3.6	2.5	0.5	5.0	2.1	0.5	2.9
	5.0	22.5	2.5	1.5	5.0	2.1	19.4	15.9
	16	54.0	15.5	6.5	5.0	1.6	69.4	16.3
	3.0	54.0	19.0	7.5	4.0	1.9	74.6	14.8
Aradayia	4.4	6.7	1.5	0.5	1.0	4.1	3.6	6.7
	5.4	20.2	3.0	1.5	3.0	2.6	19.1	13.5
	3.2	45.0	15.5	9.0	2.0	2.3	65.2	12.8
Umood	5.8	3.1	2.0	1.5	5.0	2.3	0.3	2.3
	4.6	7.2	2.0	1.0	3.0	2.3	4.9	5.9
	2.0	9.7	2.0	1.5	3.0	3.0	7.2	7.3
	3.2	9.7	2.0	0.5	2.0	3.9	6.3	8.7

The soils at Aradayia, Umood and Bangadeed are presumed to be formed from the alluvial network, which comprises myriads of seasonal streams, originating from the Nuba Mountains, which are envisaged as the main source of the alluvial deposits in this area with probable some local contaminations. Based on this information it is not surprising that the soils at Aradayia, Umood and Bangadeed are predominated by smectitic clays (Table 3). This is because the parent rocks of the Nuba Mountains are largely composed of basalt, granite, gneiss and schist (Whiteman, 1977). Each of these rocks is generally known to furnish smectitic clays on weathering. The identified chlorite in these "gardud" soils is probably a primary mineral inherited from chlorite schist rather than by pedogenesis. The soil at Kaba iselevated and has poorly sorted grain-size particles (Ø= 1.4) which respectively confute transportation by water and wind. Such deduction supports an in situ weathering of this soil. The kaolinite of the soil at Kaba is probably inherited from the sandstone parent material rather than by an advanced stage of weathering.

Table 3. The identified clay minerals of the studied "gardud" soils (25-50 cm) at North Kordofan (May-June 1996).

Location of the tested soil	Kaolinite	Smectite	Mica	Chlorite	Quartz
			%		
Kaba	69	12	5	5	9
Bangadeed	17	60	3	8	12
Aradayia	11	72	3	5	9
Umood	24	59	3	6	8

The results in Table (4) showed that sorting of soil separates of these "gardud" soils is invariably poor (Ø=1.4 to 2) as classified by Folk (1963). These results are in conformity with the presumption that the soils in Aradayia, Umood and Bangadeed are of alluvial origin; while that at Kaba has probably developed in situ from a sandstone parent rock.

Table 4. The graphic mean size and sorting of the studied "gardud" soils (0-50 cm) at North Kordofan (May-June 1996).

Location of the tested soil	Graphic mean	Sorting
Kaba	2.5	1.4
Bangadeed	3.0	2.0
Aradayia	4.0	2.0
Umood	2.3	1.9

The relatively high percentages of heavy minerals (Table 5) suggest parent materials rich in these minerals rather than these minerals being formed as a result of an advanced stage of soil weathering since these soils are young, i.e., Entisols and Inceptisols.

Based on their physical and chemical properties, the studied "gardud" soils stand a fair chance for agricultural development in the State of North Kordofan and probably elsewhere in the western states of Sudan under good management. It is suggested that pulverization of soil surface to reduce evaporation of soil moisture, chiseling to effect rapid water intake, and water harvesting techniques to increase total amount of rain water per unit area in the cultivated fields, are seen as some judicious cultural practices that should be encouraged and adopted. In addition to these practices, application of nitrogen fertilizers at low doses to match annual rainfall is envisaged as a rational cultural practice that is worth trying. The soils at Aradayia, Umood and Bangadeed are probably suited for all crops grown in this region e.g. sesame, groundnuts, millet, watermelon and sorghum; whereas, the soil at Kaba, which is relatively infertile and more prone to wind erosion, is probably best suited for natural grazing and tree crops, e.g., Acacia senegal (Hashab).

Table 5. The identified heavy minerals of the studied "gardud" soils (0-50 cm) at North Kordofan (May-June 1996).

Location of the tested soil	Zircon	Tourmaline	Rutile	Staurolite	Kyanite	Epidote	Horn-blende
				%			
Kaba	24	1	16	13	28	8	8
Bangadeed	43	1	21	14	9	7	2
Aradayia	23	11	22	33	-	-	-
Umood	24	3	27	21	9.1	9.1	6.1

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